

DEVELOPMENT OF THE SOLAR TOWER ATMOSPHERIC CHERENKOV EFFECT EXPERIMENT (STACEE)

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STACEE is a proposed telescope for ground-based gamma-ray astrophysics between 25 and 500 GeV. The telescope will make use of large mirrors available at a solar research facility to achieve an energy threshold lower than existing ground-based instruments. This paper describes recent development work on STACEE.

1 Introduction

Discoveries from the Compton Gamma Ray Observatory (CGRO)² and from ground-based experiments³ indicate that the high energy sky is rich with interesting astrophysics. Yet, there is a gap in experimental coverage between 20 and 250 GeV. Satellite instruments, such as GLAST⁴, may eventually extend their reach above 20 GeV, but the experiments with the most promise to explore the gap in the near future are ground-based detectors using the atmospheric Cherenkov technique.

The energy threshold of atmospheric Cherenkov detectors is governed by a number of parameters, of which the easiest to control is the mirror collection area.⁵ Large collection area translates into lower energy threshold, and large solar mirrors (heliostats) are readily available at existing power facilities. Since early 1994, we have been developing an experiment (STACEE) to use heliostat mirrors for Cherenkov astronomy. A similar experiment (CELESTE) is also under development in France.⁶

2 STACEE Development

Our development work has concentrated on the key issues associated with building an innovative atmospheric Cherenkov detector. We have carried out tests using prototype detector equipment at two solar heliostat fields, the Solar Two Power Plant (Barstow, CA) and the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories (Albuquerque, NM). The results from work at Solar Two have been published⁷ and in 1996, the successful tests at the NSTTF encouraged us to develop a complete instrument design using

48 heliostats at Sandia. **Documents describing the Test Results and the STACEE design can be found on the Web.**⁸ Here we *very briefly* summarize these documents.

3 Results from the Sandia Tests

We carried out two tests at Sandia (Aug. and Oct. 1996). To summarize:

- we verified that the site is suitable for Cherenkov astronomy by measuring the clarity of the sky and the ambient flux of night sky photons, and
- we determined that the heliostats have excellent pointing accuracy ($\sim 0.04^\circ$) and stability ($\sim 0.05^\circ$), and typical spot sizes of 1.5 m and reflectivities of $\sim 80\%$.

We built a complete detector prototype consisting of a 2 m secondary mirror, support structure, photomultiplier tube (PMT) camera, electronics and data acquisition system.⁸ The detector prototype performed extremely well, and it proved easy to detect atmospheric Cherenkov radiation from cosmic ray showers with little accidental background. Using these showers:

- we measured the trigger rate dependence on zenith angle, the effect of tilting the heliostats to the interaction point, and the cosmic ray spectral index, and
- from the trigger rate (5 Hz) and simulations, we determined a cosmic ray energy threshold of ~ 290 GeV for vertical showers.

The cosmic ray threshold translates into an effective gamma-ray threshold of ~ 75 GeV, indicating that the prototype instrument operated at a lower energy threshold than any atmospheric Cherenkov detector to date.

4 Overall Detector Design

The full experiment will use 48 heliostats at Sandia, corresponding to a total mirror area of $\sim 1770\text{ m}^2$. The heliostats will be divided into three sectors and Cherenkov light from each sector will be reflected onto a separate 2 m diameter secondary mirror. Each secondary will image the light onto a 16-element camera, consisting of PMTs equipped with Winston cones.

The PMT signals will be amplified and discriminated. The discriminated signals will be delayed and combined to form an overall multiplicity trigger. The amplified PMT signals will be continuously sampled by a digitizer which

will store a waveform for each PMT upon receipt of a trigger. The PMT arrival times and pulse-heights will be determined from the digitized waveforms.

Simulations show that STACEE will have a substantial collection area ($10,500\text{ m}^2$) for 50 GeV gamma-ray primaries, and that the experiment will be fully efficient by 75 GeV. In addition, the experiment should possess substantial capability to reject hadronic cosmic rays (rejection factor of ~ 210 at 50 GeV and ~ 95 at 100 GeV), as a result of the rapid decrease in the Cherenkov yield for cosmic rays below 200 GeV, the narrow field-of-view of each heliostat, the multiplicity trigger condition, and the measured lateral distribution of the Cherenkov light. From simulations we expect that STACEE will have excellent point source sensitivity ($\sim 8\sigma$ significance on the Crab in one hour).

5 Summary

We have completed the design of an innovative atmospheric Cherenkov detector sensitive to gamma-rays in an unexplored energy region. The complete experiment can be built on a two year timescale.

Acknowledgments

We thank Richard Fernholz, G.H. Marion, Antonino Miceli, Heather Ueunten, Patrick Fleury, Eric Paré, David Smith, and staff of the National Solar Thermal Test Facility. This work was supported by the National Science Foundation, the Natural Sciences and Engineering Research Council, the California Space Institute, and the University of Chicago.

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